TR-25
JULY 1968

OFFICE OF CIVIL DEFENSE

FIRE ASPECTS OF CIVIL DEFENSE

(Supersedes TR-25, dated July 1964)

PREFACE

This evaluation report was prepared by the Research Directorate, Office of Civil Defense, with the help of many suggestions by members of the Office of Civil Defense and by contractor representatives, particularly those attending the Asilomar Conference in April 1968. It is intended for use by civil defense officials and other interested persons as a summary of the best available estimates of the incendiary effects of nuclear attack. For this purpose, an effort has been made to summarize the state of knowledge in simple and direct terms and to relate this knowledge to current operational problems. In doing so, there is necessarily some loss in technical precision and detail on the one hand, and some inclusion of material that is not strictly needed for operations on the other. The latter is considered desirable, however, so that the important reasons for the incendiary behavior of nuclear weapons and the consequent threat to life and property are generally understood.

SUMMARY

This report describes the general dimensions of the fire threat resulting from nuclear attack, particularly as a result of ignition of thin materials by the thermal (heat) flash.

A review of the best available information on the thermal ignition capabilities of air-burst nuclear weapons with yields from 1 megaton to 100 megatons indicates that thermal ignitions may occur, under average to good visibility conditions, at ranges where the blast overpressure is between 1 and 3 pounds per square inch (p.s.i.), with perhaps 2 p.s.i. as a reasonable estimator of the region within which ignitions may occur.

The severity of resulting fires and the likelihood of fire spread depend on the amount and spacing of combustibles within the ignition area. Mass fires are likely only in built-up urban areas rather than in suburban or rural areas. Thus the potential ignition areas cannot be considered as a single fire area "engulfed in flame" since the controlling factors are the occurrence and size of the combustible areas rather than the ignition range of the weapon.

Experience with large fires of the past shows that only a small portion of the population at risk is killed as a result of the fire. The rate of development of large fires has been sufficiently low to permit control or movement of people to areas of relative safety. The most serious complication introduced by modern weapons is the threat of fallout that could hamper firefighting or remedial movement.

In planning a fire defense program against the threat of nuclear attack, the reduction of fire vulnerability by removing or covering ignitable materials and by reducing the concentration of combustibles in cities is equally important as the development of a capability to control and extinguish fires.

CONTENTS

FIRE ASPECTS OF CIVIL DEFENSE

INTRODUCTION

In the event of a nuclear attack on urban areas, fire may be a major threat to life and property. The detonation of a nuclear weapon results in the release of a tremendous amount of energy in a very brief period of time. A significant portion of this energy is emitted in the form of heat (thermal radiation). The thermal radiation resulting from the nuclear detonation may cause ignition of materials. Some of these ignitions will develop into sustained fires over wide areas. Blast effects, such as overturned appliances or broken gaspipes, may result in additional fires. These fires, if left unchecked, may spread and develop into mass fires.

This review will discuss several key factors affecting the firemaking potential of nuclear weapons and the threat to a population, whether in fallout shelters or not. Measures to reduce the fire hazard and to control the extent of fire damage will be cited, both those that require further research, development and planning, and those that can be undertaken immediately.

The effects of variation in yield will be illustrated for nuclear-weapon sizes ranging from 1 megaton to 100 megatons. For the present and near future, weapons with yields of up to approximately 20 megatons are considered to be the most likely offensive weapons which will be used against this country. Weapons in the 100-megaton range are not considered a likely threat, both because of the inefficiency of use and the problem of delivery to the target.

IGNITION THRESHOLDS

One of the major factors affecting the fire-raising potential of nuclear weapons is the amount of thermal radiation required to cause ignition of combustible materials. This amount of thermal radiation, known as the critical ignition energy or ignition threshold, will depend largely upon the thickness of the combustible materials. Of concern are thin combustible materials, such as newspapers and curtains, which can act as kindling fuels for heavier combustible materials. It is unlikely that thick combustible materials, such as wood siding on homes, will sustain ignition from the thermal radiation beyond the range of extensive blast destruction.

The ignition threshold is also dependent upon the rate at which the thermal radiation is delivered. As an example of the effect of the rate of delivery of thermal radiation, during a hot day the sun delivers about 700 calories per square centimeter to exposed materials on the earth's surface, but does not cause ignitions because of the low rate of delivery. When a nuclear weapon is detonated in the atmosphere, the significant thermal radiation is emitted in a matter of a few seconds. The rate of delivery is most rapid in the detonation of a small nuclear weapon and becomes significantly less rapid as the weapon size increases. As the yield of a nuclear detonation increases, the ignition threshold for a given kindling fuel also increases.

In addition to the rate of delivery of thermal radiation, the critical ignition energy is affected by the composition, color, orientation, and moisture content of the kindling fuels. Table I presents for several weapon yields the current best estimates of the critical ignition energies necessary to ignite some common kindling fuels. [1]

IGNITION POINTS AND FIRE GROWTH

The effectiveness of thermal radiation in producing ignitions is dependent upon kindling fuels that are exposed to the radiation. In order to sustain an ignition and allow development of a fire, the presence of heavier combustible materials close to the ignited kindling is required. This combination of kindling fuel and additional combustible material has been called an ignition point or "incendiary equivalent." Studies were made in several U.S. cities to estimate the frequency or occurrence of exterior and interior potential ignition points. [2] Most ignition points were found to occur indoors. Residential and commercial build-

TABLE I.—*Approximate Ignition Thresholds for Several Kindling Fuels Exposed to Burst of Nuclear Weapons in the Lower Atmosphere*

[First glowing ignition]

Kindling fuels	Ignition thresholds (cal./sq.cm.)		
	1 mt.	10 mt.	100 mt.
Newspaper, dark picture area, crumpled or folded sheets	7	11	25
Kraft corrugated paper carton, 18 oz./sq. yd	25	38	50
White typing paper	30	50	80
Light cotton curtains, 1–2 oz. black	6	9	16
Light cotton curtains, 1–2 oz. beige	32	48	70
Black roofing	-----	45	-----
Cedar shake shingles	15	26	-----
Dry rotted wood (punk) and dry thin deciduous leaves	6	8	30

ings appear to have a higher density of possible ignition points than industrial facilities. Window fuel arrays, such as curtains, shades and drapes, will probably be responsible for most sustained ignitions. These have a high probability of exposure and may be sufficiently close to other readily flammable fuels to start sustained room fires. Cotton fabrics were found to be the most prevalent tinder fuels, being found at many windows as curtains, shades or drapes.

Since most potential ignition points are found inside rooms, the thermal radiation must penetrate the window to cause an ignition. Because the thermal pulse is delivered in a matter of a few seconds, it acts before the air blast wave can destroy window glass and screens. Window glass and screens substantially reduce the thermal radiation reaching the interior of the room, as shown in table II. ([3])

ATMOSPHERIC ATTENUATION

There are two major factors which contribute to the attenuation of thermal radiation in the atmosphere: natural dispersion of the radiation and the screening effect of the atmosphere itself. As the thermal radiation from a nuclear detonation spreads through the atmosphere, it continually disperses with increasing distance from the fireball. The amount of this dispersion varies approximately inversely with the square of the distance from the source. Thus at long distances from the

TABLE II.—*Transmittance Values for Windows and Screens Whose Angle of Incidence With the Radiation Is Less Than 45 Degrees*

	Transmittance
Window screen only	0.6
Single pane window only	.8
Storm window (double pane)	.7
Single pane, with screen	.5
Storm window, with screen	.4

Note: Lowered shades and closed venetian blinds provide effective thermal shielding, although fabric parts are susceptible to ignition.

fireball, the amount of thermal energy greatly decreases.

The screening effect of the atmosphere through which the thermal radiation must pass in order to reach materials on the ground is possibly the most critical and variable factor in terms of the distance at which ignitions occur. The decreased solar radiation reaching the ground because of smog, haze and clouds over cities, and the low intensity of the sun near the horizon are examples of this screening effect.

Because of current uncertainties in atmospheric transmission, estimates of the amount of thermal radiation reaching locations 20 to 40 miles from a nuclear detonation, especially in metropolitan areas, can vary by as much as a factor of 10. Using current estimates for medium hazy and clear days in conjunction with the ignition thresholds of table I for newspaper, the ignition ranges shown in table III were obtained. ([4])

These values are indicative of the maximum ground radii (in statute miles) for ignition from the various yields. It will be noted that the ignition radius for an air burst will be between the 1- and

TABLE III.—*Comparison of Newsprint Ignition Maximum Radii and Blast Overpressure Radii*

Weapon Yield	Ignition ground radius (miles)		Blast ground radius (miles)		Height of burst (miles)
	Medium hazy day (6 mile visibility)	Clear day (12 mile visibility)	3 psi	1 psi	
1 megaton	7	8	6	13	2
10 megatons	20	26	13	28	5
100 megatons	44	59	28	60	11

the 3-p.s.i. range, depending on the visibility of the atmosphere. A better estimate of the range at which many sustained fires should occur is obtained by considering atmospheric transmission for the medium hazy and clear days in conjunction with the ignition thresholds of table I for beige cotton curtains behind a window glass and screen. These ranges are shown in table IV.

TABLE IV.—*Comparison of Biege Curtains Behind Glass and Screen Ignition Maximum Radii and Blast Overpressure Radii*

Weapon yield	Ignition ground radius (miles)		Blast ground radius (miles)		Height of burst (miles)
	Medium hazy day (6 mile visibility)	Clear day (12 mile visibility)	3 psi	1 psi	
1 megaton	2	3	6	13	2
10 megatons	7	9	13	28	5
100 megatons	19	25	28	60	11

It can be seen from table IV that the region in which substantial numbers of thermal ignitions are likely is also the region in which blast overpressures exceed 3 pounds per square inch. Tables III and IV are appropriate to detonations at a height that maximizes the extent of low overpressures (5 p.s.i.). The ignition radius for surface bursts will be smaller because of lower thermal emission from the fireball, obscuration and shielding by other structures and terrain. Since the range of low-blast overpressures is also smaller, the main fire area will remain within the 3-p.s.i. region. As the burst altitude increases, the ignition radius also increases, but at the sacrifice of blast damage effectiveness. High-altitude air bursts have been suggested as fire weapons. This threat is discussed in the next section.

CLIMATE AND WEATHER

Climate and weather may be significant factors in varying the fire-making potential of nuclear weapons. The transmission of the thermal energy to the ground, particularly from high air bursts, is strongly affected by the presence or absence of clouds, by cloud types and locations, by clearness of the air, and by other meteorological factors. Cloud transmission of thermal radiation is approximately 30 percent for light cloud to approximately 3 percent for dense cloud,(5) based on solar radiation data. For example, it has been estimated that, for a 100-megaton detonation at an altitude of 30 miles, a layer of high, thin clouds would reduce the ground ignition radius from 65 miles to 30 miles. A layer of lower, denser clouds would reduce it to 10 miles.(5)

Weather factors enter into the problem in several other ways. Foremost is the effect of moisture and moisture history on the ignitability of the materials in the target area. Ignition thresholds may be raised significantly by increased moisture. Also, the spread of fires after ignition may be influenced directly by weather conditions preceding attack, during attack, and immediately following attack.

Military planners would probably not be satisfied with a high-altitude fire attack so dependent upon weather factors. While it is conceivable that an enemy planner might choose a particularly advantageous day for the attack, the occurrence of clear skies simultaneously over all or nearly all of our major cities is extremely rare. Most of the time some of our cities have clear skies and others have cloudy skies. Under cloudy skies fires will be set but the area ignited will be smaller. So the enemy would have to settle for an uncertain chance of starting fires in a fraction of our cities as a result of attacks on all.

This difficulty facing the high-altitude incendiary attack is summarized in figure 1, which shows the percentage of time that "opaque" cloudiness (i.e., when the sun is hidden from direct view) occurs in various parts of the country. The numbers are percentages based on readings from black-bulb type sunshine recorders at 164 stations with 20 years or more of record.(6)

FIRE EFFECTS OF AIR BLAST

Many secondary fires observed in Hiroshima and Nagasaki were attributed primarily to blast effects.(7) However, the use of many "hibachis" or open fires was probably partly responsible, as well as the use of light and flammable structural materials which would not necessarily be found in U.S. cities. Flying debris and structural collapse appear to be the main sources of secondary fires. Velocities of flying debris can be high. Maximum wind velocity at 2 pounds per square inch pressure differential is approximately 70 miles per hour, and at 5 pounds per square inch it is approximately 160 miles per hour. Stoves and other heating

sources may be upset, electrical circuits and appliances may be broken, and containers of flammable gases and liquids may be ruptured, all of which would provide ignition sources or fuels.

The collapse of structures may alter the burning characteristics of the fuel, the probability of development of significant fires, and the rates of spread of such fires. Wood structures would be most vulnerable to secondary fires, particularly at longer ranges where other types of construction might withstand the blast. In many circumstances, blast-caused secondary fires may occur beyond the range at which fires are caused by thermal radiation.

MASS FIRE DEVELOPMENT

A major hazard of a nuclear attack is the development of a mass fire. In many circumstances, spreading fires will move in a downwind direction. Examples of this are the Bel Air-Brentwood fire of 1961 in Los Angeles and others which, in the past, have swept major cities and national forests. Under some vaguely defined conditions, a stationary mass fire called a "fire storm" might occur. The critical elements appear to be a large number of nearly simultaneous ignitions in a heavily constructed area, little or no ground winds and, perhaps, unstable atmospheric conditions. These conditions are not likely to occur very often. In a "fire storm," the convective currents rising from the many small fires combine in a central vertical column and cause air outside the fire area to be drawn in. This action eventually creates an intensely burning fire together with violent indrafts at its outskirts. The radial inrush velocity of the wind at the edge of the area under stable atmospheric conditions has been related to the energy release rate of single burning structures and the number of initial fires in the area.[8] The "fire storm" will burn out within 3 to 4 hours without spreading much beyond the initial fire areas.[9]

In most urban areas, a critical factor in determining the extent of fire damage might well be the likelihood of fire spread, in addition to the number of ignition points. Fire spread is largely dependent on the density and type of fuel, that is, the height and proximity of combustible buildings or of buildings with combustible contents. Topography, vegetation and wind conditions may also be key factors in fire spread, depending upon the particular locality, season and time. Mass fires, in the form of conflagrations, will continue to move downwind as long as favorable conditions exist. Eventually winds may reverse or the conflagration may reach an area where there is no fuel or where the fuel is too widely separated. Parks, large bodies of water, rocky ridges, deserts, and wide areas for highways or railroad tracks may act as barriers against fire spread. Within the area circumscribed by the ignition radius of a large weapon burst there could be several "fuel areas," each of which might support a mass fire. Scattered fires are likely to occur in the remainder of the potential ignition area.

LIFE SAFETY IN FIRE AREAS

In the fringe areas of blast, large numbers of survivors can be expected in fallout shelters like those now being marked and stocked. These shelters generally offer protection against flash burns from the initial thermal radiation. They also provide some degree of protection against blast. Therefore, many will survive the initial weapons effects in the region of one to ten pounds-per-square-inch blast overpressure. For a 10-megaton surface detonation, this region extends from 4 to 16 miles from ground zero and includes most of the damaged area.

It is in this peripheral region of survival that the secondary threat of developing fires from ignitions caused by both blast and thermal radiation will be encountered. There will be places within this general overall fire area which will have no fires. These include: (1) areas clear of any fuels; (2) fire-resistant buildings without openings exposed to the surrounding fire; or (3) buildings so located that they are not seriously exposed to the fire. Within these areas, survival is considered probable, especially for people in fallout shelters within the less fire-vulnerable buildings and in separate shelters. Moreover, there are documented reports from World War II that people survived within the fire storm area in the "bunkers" and other shelters in Hamburg and in fire-resistant buildings in Hiroshima.

An official German report on the Hamburg fire storm noted that:

> "Many Air Protection bunkers and splinter-proof surface shelters were situated in the middle of extensive area fire and fire storm zones. The heat round these buildings was more than human beings could stand. Nevertheless in no instance either in bunkers or surface shelters did shelterees come to any harm from the heat, nor did they have to leave the buildings prematurely. Shelterees remained in many of these structures until the morning after the raid and

until the fires surrounding them had abated. In some cases a covering of water had to be supplied at the exit by the Fire and Decontamination Service in order to get the occupants out. This was the case especially in special buildings situated in narrow courtyards. Often the ventilating plant could not be operated because of heat, smoke and fumes, and had to be abandoned.

"In spite of much overcrowding, air conditions even in buildings not provided with ventilating plants, as well as in bunkers full of homeless persons, remained bearable for days. The presence of openings for natural ventilation was found to be of advantage." (10)

At the time of these raids, Hamburg had an estimated population of 1.5 million. An estimated 470,000 of the people were within the area subjected to attack and heavy damage. Within this damaged area was the actual fire storm area of about 5 square miles in which there were an estimated 280,000 people. Of these, an estimated 40,000, or 14 percent, who were either in poor basement shelter or outside, were killed by blast or fire. Some 142,000 people survived in basement shelters or escaped by their own initiative, and 45,000 were rescued, in addition to an estimated 53,000 who survived in the bunkers. (11)

It is possible that areas of fire involvement in a thermonuclear attack would be significantly larger than those at Hamburg and Hiroshima, thereby making rescue and escape more difficult. This possibility would depend primarily on the size of the conflagration areas of U.S. cities. Additional studies were made of World War II attacks on nine German cities including Hamburg. (12) These cities were Barmen, Cologne, Darmstadt, Dresden, Elberfeld, Hamburg, Kassel, Krefeld, and Solingen. From these studies, urban casualty predictions have been made.

A study of past conflagrations has shown that their average speed has been less than one mile per hour, with surges of up to 3 miles per hour under the influence of strong winds. (13) These data suggest that there would be time to conduct remedial movement of threatened shelter population to areas not exposed to the fire danger, although such movement might involve exposing the people to the hazard of nuclear fallout.

Perhaps the most serious complication that the use of modern weapons has injected into the problem of life safety in fire areas is the imminent threat of nuclear fallout that could hamper firefighting or remedial movement. There would be a short period of time immediately following a detonation in which countermeasures could be undertaken. The downwind part of the area threatened by fire would shortly be threatened by fallout unless the attack had employed air bursts or high-altitude detonations. In practice, the preferred defensive actions would depend upon the relative severity of the threats of fire and fallout. Because of these threats, it would be desirable to provide a high degree of life safety from fire in fallout shelter areas through a careful selection of such areas, as well as to prepare for the prevention or control of the ignitions that might occur.

FIRE COUNTERMEASURES

The reduction of fire vulnerability is as important as planning for control and extinguishment. Many of the ways to reduce the fire hazard in times of war are essentially the same as those recommended for peacetime fire safety. Measures to make urban areas less combustible and to reduce fire losses not only result in greater safety and lower insurance rates in peacetime, but also reduce a city's vulnerability to wartime fire. It should be emphasized that countermeasures to reduce the vulnerability of an urban area fall into three categories: (1) urban design; (2) everyday actions; and (3) emergency actions.

Urban Design

The fire hazard to life may be reduced significantly through changes in the structure and composition of urban areas. The concepts of good city planning, such as residential clusters instead of disorganized urban sprawl, with ready access to arterial highways and surrounding open areas of parks or farmland, are all elements which are compatible with reducing a city's vulnerability to both peacetime and wartime fires. The design, construction and siting of buildings can reduce the incidence of primary fires.

Analysis and identification of potential conflagration areas in cities are necessities for community planning and urban renewal. The Office of Civil Defense has developed a system to assess the relative degrees of conflagration potential in urban areas subject to nuclear attack. (14) The approach is based on fire-protection knowledge and experience. Urban fire development and spread depend upon the physical arrangement and type of construction of the buildings, and the location and extent of firebreaks. Use of the system by local civil defense and fire department personnel should

markedly improve both the evaluation of the relative conflagration areas of cities and the identification of possible limiting boundaries of conflagrations.

Everyday Actions

National fire prevention, cleanup and family safety programs, and local fire inspections by fire marshals and fire departments are significant everyday actions that help reduce fire vulnerability. The adoption and enforcement of model building codes are essential in controlling undesirable construction. Support of these programs, especially those that continue throughout the year, will help reduce the vulnerability of a city to wartime fires.

Emergency Actions

Good fire-prevention practices can prevent many fires which might otherwise occur during a nuclear attack. Trash should not be allowed to accumulate, especially near heat sources. Flammable liquids should be stored with great care, preferably out of doors. Faulty electric circuits should be repaired quickly and circuits should not be overloaded. Electrical appliances, such as irons, should be disconnected. Electricity and gas should be turned off.

Windows, particularly large ones, should be coated with whitewash, household cleaning powders, or other soluble opaque materials, even mud in an emergency. Metal venetian blinds should be lowered and closed. Easily ignitable curtains should be removed from windows. At such a time of emergency, window coatings can easily be monitored from outside by firemen, block wardens, police, or others. Inside houses and buildings, easily ignitable furniture, such as chairs and sofas, should be removed from window areas.

The garden hose, available in almost all homes, should be connected and ready for use. Water and sand should be stored in bath tubs and other containers. Blankets, towels and other fire-fighting cloths should be ready for wetting and use. Fire extinguishers should be ready for instant use. However, caution should be exercised when using vaporizing-liquid types of extinguishers in small enclosed spaces.

Bulky pieces of furniture, such as chairs, sofas or beds, which catch on fire may be taken out of the house. With electrical fires, the electricity should be disconnected first. If it cannot be disconnected, water should not be used in fighting the fire. With an oil fire, the oil supply should be cut off first. Then the fire should be smothered with sand, dirt, heavy rugs or materials. Water should not be used. With a gas fire, the gas supply should be disconnected first. Then water, sand or dirt may be used to put out the fire.

It should be remembered that the three components of fire fighting are:

(1) Take away fuel.
(2) Take away the oxygen (smother fire).
(3) Cool fire with water or other extinguishing materials.

NOTES

1. The estimates in table I for ignition thresholds of kindling fuels are based on experimental measurements made by the U.S. Naval Applied Science Laboratory, the U.S. Naval Radiological Defense Laboratory, and the IIT Research Institute using radiant pulse simulators developed at each laboratory. The results are generally in good agreement. Variations, such as color, weave, weight, density, and moisture content, can materially affect a kindling fuel's ignition threshold. For example, a dirty, crumpled, and loosely folded newspaper exposed to a 100-megaton detonation in the lower atmosphere would require only 25 cal. per square cm. (as given in table I) for ignition, while a single sheet of finely printed text would require approximately 45 cal. per square cm. The reduction under similar circumstances for a 10-megaton detonation was only from 12 to 11 cal. per square cm.
2. Bracciaventi, J., S. Feldman, and R. Newman, *Fuel Array Survey of Providence, Rhode Island*, U.S. Naval Applied Science Laboratory, Brooklyn, N.Y., September 1967. AD 825 200L. A similar study by this group is nearly completed for Detroit, Mich.
   Keller, J. A. and T. E. Lommasson, *Survey of Fuel Arrays Ignitable by Nuclear Weapon Thermal Pulse in Albuquerque, N. Mex.*, The Dikewood Corporation, Albuquerque, N. Mex., March 1967, AD 817 623L.
3. Bracciaventi, J., *Window and Window Screens as Modifiers of Thermal Radiation Released in Nuclear Detonations*, U.S. Naval Applied Science Laboratory, Brooklyn, N.Y., Sept. 12, 1966, p. 9.

4. Gibbons, Mathew G., *Transmissivity of the Atmosphere for Thermal Radiation from Nuclear Weapons*, U.S. Naval Radiological Defense Laboratory, San Francisco, Calif., Aug. 12, 1966. AD 641 481.
5. Passell, T. O., *Transmission by the Earth's Atmosphere of Thermal Energy from Nuclear Detonations Above 50 km Altitude*, Stanford Research Institute, Menlo Park, Calif., Apr. 30, 1963. AD 404 590.
6. Figure 1 is adapted from *National Atlas of the United States*, "Mean Percentages of Possible Sunshine," Prepared by Office of Climatology, 1960.
7. McAuliffe, John, and Kendall Moll, *Secondary Ignitions in Nuclear Attack*, Stanford Research Institute, Menlo Park, Calif., July 1965. AD 625 173.
8. Lommasson, T. E., *Preliminary Investigation of Fire Storm Start Criteria*, Dikewood Corporation, Albuquerque, N. Mex. June 15, 1965.
9. Chandler, Craig C., *A Study of Mass Fires and Conflagrations*, U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, Calif., 1963. PSW–N22. This publication was based on a study of past mass fires by the U.S. Forest Service for the Office of Civil Defense.
10. Police President of Hamburg, *Report by the Police President of Hamburg and local Air Protection leader of Hamburg on the large scale raids on Hamburg in July and August 1943*, Experiences, vol. 1: Report, (translation), p. 88.
11. Earp, Kathleen F., *Deaths from Fire in Large Scale Air Attack—with special reference to the Hamburg Fire Storm*, British Home Office, Scientific Adviser's Branch, London, April 1953, CD/SA 28.
12. Davis, L. W., D. L. Summers, and J. A. Keller, *Prediction of Prompt-Thermal and Fire Casualties from a High-Yield Nuclear Burst*, Dikewood Corporation, Albuquerque, N. Mex. Paper delivered at the Technical Cooperation Program, Panel N–2 (Thermal), Falfield, Gloucestershire, England, Mar. 25–29, 1968. Sponsored by Office of Civil Defense. DC–P–1060–2.
13. Chandler, Craig C., *A Study of Mass Fires and Conflagrations*, U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, Calif., 1963. PSW–N22.
14. Cohn, B. M., L. E. Almgren, and M. Curless, *A System for Local Assessment of the Conflagration Potential of Urban Areas*, Gage-Babcock and Associates, Inc., Chicago, Ill., March 1965. AD 616 623.

Distribution:
OCD Regions, Staff College
State and Local CD Directors
Defense Coordinators of Federal Agencies
Architects and Engineers Qualified in FO Shelter Analysis
CE–NAVFAC Field Offices
Technical Universities
Professional Societies Interested in Protective Construction
Industrial Training Directors
Foreign Activities
Engineering Libraries of Educational Institutions

U.S. GOVERNMENT PRINTING OFFICE: 1968 O—310-812